

# **Launch Vehicle Mass Estimating Relationship Database**

## **FINAL REPORT**

REF: Order Number H-28653D  
(Part II)

1 December, 1999

Submitted to:  
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# ARCHITECTURAL BREAKDOWN STRUCTURE ITEM

Brothers DEC 1, 1999 4:00 PM

Primary structures:

ALUMINUM STRUCTURES UNLESS NOTED OTHERWISE

Primary Fuselage MER=2.167\*barea^1.075 Orbiter and/or Aircraft type vehicles

Nose structure

Right cone

prim: Nose stru

sec: MAX Q=800

MER=NOSE\_AREA\*((14.31-3.462E-3\*Q)\*NOSE\_ANGLE\*(1.034E-4\*Q-.5878)+(6.864E-4-6.1E-9\*Q)\*NOSE\_ANGLE+(4.385E-5\*Q-.037))\*NOSE\_DIAMETER)  
MER=NOSE\_CONE\_AREA\*((6.656E-4\*NOSE\_CONE\_ANGLE-1.0787E-3)\*NOSE\_CONE\_DIAMETER+2.8888-0.026777\*NOSE\_CONE\_ANGLE)

Ellipsoid Shape h=1.67r

prim: Nose stru

sec: MAX Q=800

MER=NOSE\_STR\_AREA\*(2.499E-4\*QMAX+1.7008+(3.695E-5\*QMAX-3.252E-3)\*NOSE\_STR\_DIAMETER)  
MER=NOSE\_STR\_AREA\*(1.8963+0.02671\*NOSE\_STR\_DIAMETER)

Interstage

stage 1 of 1  
stage 1 of 2  
stage 2 of 2  
stage 1 of 3  
stage 2 of 3  
stage 3 of 3  
stage 1 of 4  
stage 2 of 4  
stage 3 of 4  
stage 4 of 4

MER=INTERSTAGE\_AREA\*17.92\*bwidth^0.4856  
MER=INTERSTAGE\_AREA\*18.57\*bwidth^0.4856  
MER=INTERSTAGE\_AREA\*22.94\*bwidth^0.6751  
MER=INTERSTAGE\_AREA\*19.95\*bwidth^0.4856  
MER=INTERSTAGE\_AREA\*17.74\*bwidth^0.4856  
MER=INTERSTAGE\_AREA\*22.94\*bwidth^0.6751  
MER=INTERSTAGE\_AREA\*21.65\*bwidth^0.4856  
MER=INTERSTAGE\_AREA\*18.40\*bwidth^0.4856  
MER=INTERSTAGE\_AREA\*16.94\*bwidth^0.4856  
MER=INTERSTAGE\_AREA\*22.94\*bwidth^0.6751

LOAD CARRING TRANSITION STRUCTURE BETWEEN SHROUD/PAYLOAD AND FIRST STG  
LOAD CARRING TRANSITION STRUCTURE BETWEEN STAGES  
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LOAD CARRING TRANSITION STRUCTURE BETWEEN SHROUD/PAYLOAD AND FIRST STG

Forward skirt

stage 1 of 1  
stage 1 of 2  
stage 2 of 2  
stage 1 of 3  
stage 2 of 3  
stage 3 of 3  
stage 1 of 4  
stage 2 of 4  
stage 3 of 4  
stage 4 of 4

MER=FORWARD\_SKIRT\_AREA\*37.35\*bwidth^0.6722  
MER=FORWARD\_SKIRT\_AREA\*38.70\*bwidth^0.6722  
MER=FORWARD\_SKIRT\_AREA\*15.46\*bwidth^0.5210  
MER=FORWARD\_SKIRT\_AREA\*41.58\*bwidth^0.6722  
MER=FORWARD\_SKIRT\_AREA\*28.80\*bwidth^0.6042  
MER=FORWARD\_SKIRT\_AREA\*15.46\*bwidth^0.5210  
MER=FORWARD\_SKIRT\_AREA\*45.07\*bwidth^0.6722  
MER=FORWARD\_SKIRT\_AREA\*32.88\*bwidth^0.6283  
MER=FORWARD\_SKIRT\_AREA\*24.85\*bwidth^0.5784  
MER=FORWARD\_SKIRT\_AREA\*15.46\*bwidth^0.5210

LOAD CARRING STRUCTURE BETWEEN INTERSTAGE AND FIRST PROPELLANT TANK  
LOAD CARRING STRUCTURE BETWEEN INTERSTAGE AND FIRST PROPELLANT TANK  
LOAD CARRING STRUCTURE BETWEEN INTERSTAGE AND FIRST PROPELLANT TANK  
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LOAD CARRING STRUCTURE BETWEEN INTERSTAGE AND FIRST PROPELLANT TANK

Oxidezer tank

MER=(2.42-0.00271\*oxid\_d)\*oxid\_vtank\*(0.8445+0.00047\*oxid\_d)  
MER=(1.3012+0.0099\*OXID\_TANK\_PRESSURE)\*oxid\_vtank\*(0.8647\*OXID\_TANK\_PRESSURE^0.01645)  
PRESS-FED ENGINE STAGE, tank pressure 150-1200psi

PUMP-FED ENGINE STAGE, tank pressure < 55 psi

Intertank

stage 1 of 1  
stage 1 of 2  
stage 2 of 2  
stage 1 of 3

MER=INTERTANK\_AREA\*26.36\*bwidth^0.5169  
MER=INTERTANK\_AREA\*27.04\*bwidth^0.5169  
MER=INTERTANK\_AREA\*21.47\*bwidth^0.6025  
MER=INTERTANK\_AREA\*28.54\*bwidth^0.5169

LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS  
LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS  
LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS  
LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS

stage 2 of 3	MER=INTERTANK_AREA * 25.54*bwidth^0.5472	LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS
stage 3 of 3	MER=INTERTANK_AREA * 20.62*bwidth^0.6025	LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS
stage 1 of 4	MER=INTERTANK_AREA * 30.39*bwidth^0.5169	LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS
stage 2 of 4	MER=INTERTANK_AREA * 28.05*bwidth^0.5353	LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS
stage 3 of 4	MER=INTERTANK_AREA * 24.12*bwidth^0.5616	LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS
stage 4 of 4	MER=INTERTANK_AREA * 19.76*bwidth^0.6025	LOAD CARRING STRUCTURE BETWEEN PROPELLANT TANKS
Fuel1 tank	MER=(2.42 - 0.00271*fuel1_d)*fuel1_vtank^(0.8445+0.00047*fuel1_d) MER=(1.3012 + 0.0099 * FUEL1 TANK PRESSURE)*fuel1_vtank^(0.8647*FUEL1 TANK PRESSURE^0.01645)	PUMP-FED ENGINE STAGE, tank pressure < 55 psi
Fuel2 tank	PRESS-FED ENGINE STAGE, tank pressure 150-1200psi MER=(2.42 - 0.00271*fuel2_d)*fuel2_vtank^(0.8445+0.00047*fuel2_d) MER=(1.3012 + 0.0099 * FUEL2 TANK PRESSURE)*fuel2_vtank^(0.8647*FUEL2 TANK PRESSURE^0.01645)	PUMP-FED ENGINE STAGE, tank pressure < 55 psi
Mono-propellant tank	PRESS-FED ENGINE STAGE, tank pressure 150-1200psi MER=(2.42 - 0.00271*mono_d)*mono_vtank^(0.8445+0.00047*mono_d) MER=(1.3012 + 0.0099 * MONO TANK PRESSURE)*mono_vtank^(0.8647*MONO TANK PRESSURE^0.01645)	PUMP-FED ENGINE STAGE, tank pressure < 55 psi
Solid propellant case add	PRESS-FED ENGINE STAGE, tank pressure 150-1200psi MER=solid_vcase*((1.07E-7*bwidth+9.1014E-3)*946-(8.537E-4*bwidth-6.483E-3))-(9.1677E-7*(bwidth*12)^3.008*946+53.65-4.128*bwidth)	
Solid propellant nozzle	STEEL case MER=1.085E-6*(bwidth*12)^3*946+4.142E-5*ispvac*solid_caseprop	AFT section of Solid Motor
Hybrid fuel case add	MER=hyfuel_vcase*((1.07E-7*bwidth+9.1014E-3)*946-(8.537E-4*bwidth-6.483E-3))-(9.1677E-7*(bwidth*12)^3.008*946+53.65-4.128*bwidth)	
Hybrid fuel nozzle	STEEL case MER=1.085E-6*(bwidth*12)^3*946+4.142E-5*ispvac*(hyfuel_caseprop+oxid_tankprop)	AFT section of Hybrid Motor
Thrust structure	MER=1.949E-3*(lvac)^1.0687	inline launch vehicle type propulsion system
Thrust structure	MER=7.995E-4*(lvac)^1.0687	side-mount and/or orbiter type propulsion module
Engine compartment		
stage 1 of 1	MER=ENGINE_COMPARTMENT_AREA * 31.66*bwidth^0.54	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND VEHICLE HOLD-DOWN
stage 1 of 2	MER=ENGINE_COMPARTMENT_AREA * 32.48*bwidth^0.54	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND VEHICLE HOLD-DOWN
stage 2 of 2	MER=ENGINE_COMPARTMENT_AREA * 15.97*bwidth^0.48	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND INTSTG OF NEXT STG
stage 1 of 3	MER=ENGINE_COMPARTMENT_AREA * 34.26*bwidth^0.54	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND VEHICLE HOLD-DOWN
stage 2 of 3	MER=ENGINE_COMPARTMENT_AREA * 24.88*bwidth^0.51	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND INTSTG OF NEXT STG
stage 3 of 3	MER=ENGINE_COMPARTMENT_AREA * 15.17*bwidth^0.48	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND INTSTG OF NEXT STG
stage 1 of 4	MER=ENGINE_COMPARTMENT_AREA * 36.50*bwidth^0.54	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND VEHICLE HOLD-DOWN
stage 2 of 4	MER=ENGINE_COMPARTMENT_AREA * 29.70*bwidth^0.51	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND INTSTG OF NEXT STG
stage 3 of 4	MER=ENGINE_COMPARTMENT_AREA * 22.04*bwidth^0.51	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND INTSTG OF NEXT STG
stage 4 of 4	MER=ENGINE_COMPARTMENT_AREA * 14.70*bwidth^0.48	LOAD CARRING STRUCT BETWEEN AFT PROP TANK/THRUST STRUCT AND INTSTG OF NEXT STG
Aft skirt	MER=AFT_SKIRT_AREA*(2.499E-4*QMAX+1.7008+(3.695E-5*QMAX-3.252E-3)*bwidth)	
Stg-to-stg attach str	Non-load carrying aerodynamic structure or fairing MER=0.0148*(mgross_stg+mpayld)	
Stg-to-stg attach str	Orbiter type vehicle to ET or Booster Stage attach structures which stays with ET or Booster stage MER=1.148E-3*(mstrapon)	
Stg-to-stg attach str	SRB's and/or LRB's to ET or Core Stage attach structures which stays with ET or Core stage MER=3.14E-4*(mstrapon)	

Misc primary str items	SRB's and/or LRB's attach structures which stays with SRB's or LRB's included with each primary structure item, other misc weights are accounted for in the weight contingency		
	Secondary Structures		
Crew cabin	MER=28.31*(39.66*(N_CREW*N_DAYS)^1.002)^0.6916		
P/L bay doors & hdw	Volume required for the crew is calculated as 39.66*(N_CREW*N_DAYS)^1.002 MER=0.257*barea/2	typical STS Orbiter N_CREW=7 and N_DAYS=10 typical STS orbiter type system, barea(STS Orbiter=6257 ft^2)	
P/L bay support	MER=0.2336*barea/2	typical STS orbiter type system	
P/L container Internal or	MER=4808*barea	typical STS orbiter type system	
P/L container External	MER=0.7*mpayld	External expendable and detachable payload container/shroud side mounted concept, sized by Larc from composites	
Base closeout	included in Aft Structures or Primary Fuselage		
Aft OMS/RCS pod	MER=0.0117*mjett	typical STS orbiter type system, mjett(STS Orbiter)=254000 lbs	
Fwd RCS Module	MER=1.52E-3*mjett	typical STS orbiter type system	
Jet engine fairings	MER=0.055*.175*mjett	sized based on Roskam eq 5.36, similar to KC13 includes nacelle weights and fairings for cruise-back jet engines	
Jet fuel tank	MER=2.433*((280*tburn/150)/364*.881*.175*mjett^1.1/50.25)^.878	fuel tank scaling equation, 10% (residuals+ullage+reserves) included	
Jet fuel tank support	MER=(2.433*((280*tburn/150)/364*.881*.175*mjett^1.1/50.25)^.878)^.15	typical support structures estimate	
Misc secondary str items: included with each secondary structure item, other misc weights are accounted for in the weight contingency			
Wing Group:			
Exposed Wings	primary	MER=1575*(mland*3.75*span_theo_wing*area_pf_wing/(rc_exp_wing*tkrat_exp_wing*1E9))^.67	
	secondary	Larc AVID equation adj to STS Orb Technology: mland=214k, 3.75=ULF, span=78.1 ft, area=2012.4 ft^2, rc=689.24/12, tkrat=113	
Wing carry-thru	primary	power curve fit of aircraft and STS Orbiter: exposed wing weight and area only	
	secondary	MER=1.06*rc_exp_wing*chru_wing/area_theo_wing*1575*(mland*3.75*span_theo_wing*area_pf_wing/(rc_exp_wing*tkrat_exp_wing*1E9))^.67	
Wing fairings	primary	typical STS Orb: chru=17.5 ft, theo wing=2690 ft^2	
	secondary	MER=WING_FAIRINGS_AREA*(2.499E-4*QMAX+1.7008+(3.695E-5*QMAX-3.252E-3)*bwidth)	
Non-load carrying aerodynamic fairing			
Empennage Group	primary	MER=26.06*((area_pf_fins)^0.901*(tkrat_fins)^0.244*(span_fins)^0.0364)^0.8674	
	secondary	Boeing aircraft vertical tail equation power curve fit with STS Orb and aircraft data	
Vertical tail	primary	MER=9.67*(area_pf_fins)^0.9283	
	secondary	power curve fit of aircraft and STS Orbiter: vertical tail weight and area only	

T

primary  
 $MER=26.06*((area\_pf\_vtail)^{0.901}*(tkrat\_vtail)^{0.244}*(span\_vtail)^{0.0364})^{0.8674}$   
 Boeing aircraft vertical tail equation power curve fit with STS Orb and aircraft data  
 secondary  
 $MER=9.67*(area\_pf\_vtail)^{0.9283}$   
 power curve fit of aircraft and STS Orbiter: vertical tail weight and area only  
 Vertical tail spar  
 $MER=tc\_vtail/2*span\_vtail/area\_pf\_vtail^{26.06}*((area\_pf\_vtail)^{0.901}*(tkrat\_vtail)^{0.244}*(span\_vtail)^{0.0364})^{0.8674}$   
 ratio of 1/2 \*tc\*span to planform area \* vtail wt  
 Vertical tail fairing  
 $MER=VERTICAL\_TAIL\_FAIRING\_AREA*(2.499E-4*QMAX+1.7008+(3.695E-5*QMAX-3.252E-3)*bwidth)$   
 Non-load carrying aerodynamic fairing  
 Canard  
 primary  
 $MER=5.107*(area\_pf\_can^{1.199}*tkrat\_can^{0.385})^{0.9117}$   
 Boeing aircraft horizontal tail equation power curve fit with STS Orb and aircraft data  
 secondary  
 $MER=3.059*area\_pf\_can^{1.086}$   
 power curve fit of aircraft and STS Orbiter: horizontal tail weight and area only  
 Canard carry-thru  
 $MER=rc\_can*CTHRU\_CANARD/(area\_pf\_can+rc\_can*CTHRU\_CANARD)*5.107*(area\_pf\_can^{1.199}*tkrat\_can^{0.385})^{0.9117}$   
 ratio of carry-thru area to total area of canard and carry-thru \* canard wt  
 Canard fairings  
 $MER=CANARD\_FAIRINGS\_AREA*(2.499E-4*QMAX+1.7008+(3.695E-5*QMAX-3.252E-3)*bwidth)$   
 Non-load carrying aerodynamic fairing

Horizontal tail  
 primary  
 $MER=5.107*(area\_pf\_htail^{1.199}*tkrat\_htail^{0.385})^{0.9117}$   
 Boeing aircraft horizontal tail equation power curve fit with STS Orb and aircraft data  
 secondary  
 $MER=3.059*(area\_pf\_htail)^{1.086}$   
 power curve fit of aircraft and STS Orbiter: horizontal tail weight and area only  
 Horiz tail carry-thru  
 $MER=rc\_htail*CTHRU\_HTAIL/(area\_pf\_htail+rc\_htail*CTHRU\_HTAIL)*5.107*(area\_pf\_htail^{1.199}*tkrat\_htail^{0.385})^{0.9117}$   
 ratio of carry-thru area to total area of horizontal tail and carry-thru \* horizontal tail wt  
 Horizontal tail fairing  
 $MER=HORIZONTAL\_TAIL\_FAIRING\_AREA*(2.499E-4*QMAX+1.7008+(3.695E-5*QMAX-3.252E-3)*bwidth)$   
 Non-load carrying aerodynamic fairing

Body flap  
 $Mer=3.421*AREA\_BFLAP$

Landing Gear Group  
 Linear w/area equation derived from STS Orbiter data, area=135.75 ft^2  
 $MER=0.010784*mland^{1.0861}$

Nose Gear  
 Power curve fit of aircraft and STS Orbiter data, mland Orb(max design)=214k  
 $MER=0.001514*mland^{1.0861}$   
 runing gear  
 $MER=0.2*(0.001514*mland^{1.0861})$  ratios derived from STS Orbiter data  
 structures  
 $MER=0.64*(0.001514*mland^{1.0861})$  ratios derived from STS Orbiter data  
 controls&m  
 $MER=0.16*(0.001514*mland^{1.0861})$  ratios derived from STS Orbiter data

Main Gear  
 $MER=0.00927*mland^{1.0861}$   
 runing gear  
 $MER=0.4*(0.00927*mland^{1.0861})$  ratios derived from STS Orbiter data  
 structures  
 $MER=0.48*(0.00927*mland^{1.0861})$  ratios derived from STS Orbiter data  
 controls&m  
 $MER=0.12*(0.00927*mland^{1.0861})$  ratios derived from STS Orbiter data

Recovery systems:

Parachutes  
 $MER=0.06*mland$   
 data derived from 1987 Boeing p/a ballistics module study and STS SRB data  
 Parafalls  
 $MER=0.075*mland$   
 data derived from 1990 Pioneer Advanced Recovery Systems Study

A

oxidizer feed sy	MER=1.371*mdot*oxid_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter + ET type configuration
	MER=1.272*mdot*oxid_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter with internal propellant tanks configuration
	MER=0.818*mdot*oxid_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter w/o propellant tanks configuration
	MER=0.553*mdot*oxid_frac*(1+.04*IF(cross_feed=1,1,0))	ET type tank only configuration
	MER=1.116*mdot*oxid_frac*(1+.04*IF(cross_feed=1,1,0))	Booster configuration
fuel1 feed sys	MER=7.153*mdot*fuel1_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter + ET type configuration
	MER=6.625*mdot*fuel1_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter with internal propellant tanks configuration
	MER=5.465*mdot*fuel1_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter w/o propellant tanks configuration
	MER=1.688*mdot*fuel1_frac*(1+.04*IF(cross_feed=1,1,0))	ET type tank only configuration
	MER=0.8088*mdot*fuel1_frac*(1+.04*IF(cross_feed=1,1,0))	Booster configuration
fuel2 feed sys	MER=7.153*mdot*fuel2_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter + ET type configuration
	MER=6.625*mdot*fuel2_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter with internal propellant tanks configuration
	MER=5.465*mdot*fuel2_frac*(1+.04*IF(cross_feed=1,1,0))	Orbiter w/o propellant tanks configuration
	MER=1.688*mdot*fuel2_frac*(1+.04*IF(cross_feed=1,1,0))	ET type tank only configuration
	MER=0.8088*mdot*fuel2_frac*(1+.04*IF(cross_feed=1,1,0))	Booster configuration
Mono-prop feed		
Pressurization system		
Total system		
	MER=1.022*mdot	booster or upper stage configuration
	MER=0.192*mdot	Orbiter + ET type configuration
	MER=0.178*mdot	Orbiter with internal propellant tanks configuration
	MER=0.047*mdot	Orbiter w/o propellant tanks configuration
	MER=0.145*mdot	ET type tank only configuration
	MER=0.266*mdot	Booster configuration
Oxidizer press		
	MER=0.090*mdot*oxid_frac	Orbiter + ET type configuration
	MER=0.084*mdot*oxid_frac	Orbiter with internal propellant tanks configuration
	MER=0.022*mdot*oxid_frac	Orbiter w/o propellant tanks configuration
	MER=0.068*mdot*oxid_frac	ET type tank only configuration
	MER=0.07*mdot*oxid_frac	Booster configuration
Fuel1 press sys		
	MER=0.804*mdot*fuel1_frac	Orbiter + ET type configuration
	MER=0.745*mdot*fuel1_frac	Orbiter with internal propellant tanks configuration
	MER=0.196*mdot*fuel1_frac	Orbiter w/o propellant tanks configuration
	MER=0.608*mdot*fuel1_frac	ET type tank only configuration
	MER=0.724*mdot*fuel1_frac	Booster configuration
Fuel2 press sys		
	MER=0.804*mdot*fuel2_frac	Orbiter + ET type configuration
	MER=0.745*mdot*fuel2_frac	Orbiter with internal propellant tanks configuration
	MER=0.196*mdot*fuel2_frac	Orbiter w/o propellant tanks configuration
	MER=0.608*mdot*fuel2_frac	ET type tank only configuration
	MER=0.724*mdot*fuel2_frac	Booster configuration
Mono-prop press		
	MER=0.266*mdot	booster or upper stage configuration
Purge systems		
	MER=bvol*0.053	Orbiter type purge system

TVC hardware	MER=0.001185*lvac	average sys wt of STS Obiter and Saturn vehicles	
Auxiliary Propulsion:			
RCS total system	MER=0.0126*mjett	sized based on Orbiter with mjett = 254000 lbs	
RCS:			
Thrusters & sup	MER=0.0058*mjett	sized based on Orbiter with mjett = 254000 lbs	
Prop tanks & sup	MER=0.0046*mjett	sized based on Orbiter with mjett = 254000 lbs	
Distribution sys	MER=0.0023*mjett	sized based on Orbiter with mjett = 254000 lbs	
OMS total system	MER=0.0121*mjett	sized based on 1000 ft/sec delta V and Orbiter mjett = 254000 lbs	
OMS:			
Engines & suppt	MER=0.0025*mjett	sized based on 1000 ft/sec delta V and Orbiter mjett = 254000 lbs	
Prop tanks & sup	MER=0.0045*mjett	sized based on 1000 ft/sec delta V and Orbiter mjett = 254000 lbs	
Feed system	MER=0.002*mjett	sized based on 1000 ft/sec delta V and Orbiter mjett = 254000 lbs	
Press system	MER=0.003*mjett	sized based on 1000 ft/sec delta V and Orbiter mjett = 254000 lbs	
Jet engines(cruise-back	MER=0.175*mjett/10988*3940	sized based on LFBB study mjett=269000 lbs,F-110 jet eng :10988 lbs-thr, 3940 lbs, SFC= .881	
Jet propellant(cruise)	MER=280*lburn/150/364*.881*.175*mjett	sized based on LFBB study mjett=269000 lbs,364 nm/hr cruise, F-110 jet eng: SFC= .881	
Jet engine support	MER=0.27*(.175*mjett/10988*3940)	derived from aircraft data	
Avionics total system	MER=1876+506*masccprop/1.6E6+4245*N_DAYS/7+12522*N_CREW/7	Data scaled from EHLV study, Shuttle C study, and Orbiter	
Avionics :			
GN&C	MER=242+108*N_DAYS/7+617*N_CREW/7	Data scaled from EHLV study, Shuttle C study, and Orbiter	
Communications	MER=131*N_DAYS/7+1400*N_CREW/7		
Data mgmt/hand	MER=302+828*N_DAYS/7+1010*N_CREW/7		
Range Safty	MER=0.27*barea		
Power systems:			
Electrical power:			
Batteries	MER=216+952*N_DAYS/7*(1/(N_CREW=0.1.0))	Data scaled from EHLV study, Shuttle C study, and Orbiter	
Fuel cells	MER=3030*N_CREW/7	unmanned mission only	
Conv & distr	MER=793+506*masccprop/1.6E6+2226*N_DAYS/7+7633*N_CREW/7		
Hydr & pneumat	MER=0.426*((area_theo_wing+area_pl_vtail+area_pl_htail+AREA_BFLAP)*QMAX/1000)^1.1143+0.001785*lvac		
Personnel Provisions + crew	MER=2444*N_CREW/7+645*N_CREW+86.4*N_DAYS	based on Orbiter data N_CREW=7,N_DAYS=7	
Payload Provisions	0.025*mpayld	based on Orbiter data SD72-SH-0120-228.12/91	
Mass contingency	0.00%	Derived from data developed by Program Development PD24 (80-22)	
		Weights based on existing structures, hardware, engines, and/or subsystems which require no modifications	

5.00%	Weights based on existing structures, hardware, engines, and/or subsystems which require some modifications
10.00%	Weights based on new designs which use existing type materials and subsystems.
15.00%	Weights based on new designs which use existing type materials and subsystems which require limited development in materials and technology
20% to 25%	Weights based on new designs which require extensive development in materials and technology
Structure weight reduction	
0%	Derived from data provided by Airframe Team Sept, 1999 Structural designs based on current AL alloy ie saturn V, orbiter, ET tank, and other existing NASA programs.
10.00%	Structural designs based on AL-LI alloy ie new light-weight AL-LI ET tank.
20.00%	Wing structural designs based on advanced composites and materials
25.00%	Propellant tanks structural designs based on advanced composites and materials
30.00%	Interstages and body structural designs based on advanced composites and materials

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